Claims

1. A phoretic cell comprising a liquid crystal cell having a liquid crystal material and a phoretic particle therein, the phoretic particle being moveable from a first preferred position at a first side of the liquid crystal cell to a second side of the liquid crystal cell on application of a field,

the liquid crystal cell being adapted such that, when the phoretic particle is not located at the first preferred position, there is a defect associated with the first preferred position and the liquid crystal defect energy of said defect is lower when the phoretic particle is located substantially at the first preferred position within the liquid crystal cell than when the phoretic particle is not so located.

2. A phoretic cell according to claim 1 wherein the applied field must exceed a threshold level to move the phoretic particle from the first preferred position to the second side of the liquid crystal cell.

3. A phoretic cell according to claim 1 or 2 wherein the phoretic particle is moveable reversibly from a second preferred position at the second side of the liquid crystal cell to the first preferred position at the first side of the liquid crystal cell on application of a field,

the liquid crystal cell being adapted such that, when the phoretic particle is not located at the second preferred position, there is a defect associated with the second preferred position and the liquid crystal defect energy of said defect is lower when the phoretic particle is located substantially at the second preferred position within the liquid crystal cell than when the phoretic particle is not so located.

4. A phoretic cell according to claim 3 wherein the applied field must exceed a threshold level to move the phoretic particle from the second preferred position to the first preferred position within the liquid crystal cell.

5. A phoretic cell according to claim 4 wherein the magnitude of the threshold level associated with moving the phoretic particle from the first preferred position to the

second preferred position within the liquid crystal cell is different to that for moving the phoretic particle from the second preferred position to the first preferred position within the liquid crystal cell.

6. A phoretic cell according to any of claims 1-5 having a plurality of first preferred positions at the first side of the liquid crystal cell, each first preferred position having a defect associated therewith, and a plurality of phoretic particles dispersed within the liquid crystal material.

7. A phoretic cell according to claim 6 when dependent on claim 3 having a plurality of second preferred positions at the second side of the liquid crystal cell, each second preferred position having a defect associated therewith.

8. A phoretic cell according to claim 6 or 7 wherein at least one internal surface of the liquid crystal cell is profiled so as to induce said defects.

9. A phoretic cell according to claim 8 wherein the profile comprises a plurality of indentations arranged in an array.

10. A phoretic cell according to claim 9 wherein the indentations are arranged in a regular array.

11. A phoretic cell according to claim 10 wherein the array comprises a two-dimensional array and the indentations are arranged in a close-packed configuration therein.

12. A phoretic cell according to claim 11 wherein the indentations are arranged in a hexagonal close-packed configuration within the array.

13. A phoretic cell according to any of claims 9 - 12 wherein the indentations comprise substantially semi-ellipsoidal indentations.

14. A phoretic cell according to claim 13 wherein the indentations comprise substantially semi-spheroidal indentations.

15. A phoretic cell according to claim 14 wherein the indentations comprise substantially semi-spherical indentations.

16. A phoretic cell according to claim 15 wherein the indentations comprise substantially hemispherical indentations.

17. A phoretic cell according to any of claims 9 - 16 wherein the indentations are arranged at a pitch, p, within the array and each indentation has a depth, d.

18. A phoretic cell according to claim 17wherein the ratio of the depth of the indentations, d, to the pitch of the indentations, p, is at least a quarter.

19. A phoretic cell according to any of claims 3 - 5 wherein the liquid crystal cell comprises a liquid crystal droplet.

20. A phoretic cell according to claim 19 wherein the phoretic cell comprises a plurality of liquid crystal cells.

21. A phoretic cell according to claim 20 wherein the liquid crystal droplets are substantially spherical, each liquid crystal droplet having a length, L, equal to the droplet diameter D.

22. A phoretic cell according to claim 20 wherein the liquid crystal droplets are substantially prolate spheroids, each liquid crystal droplet having a length, L, measured along the major axis and a diameter, D, measured along the minor axis of the liquid crystal droplet, and the first and second preferred positions are arranged substantially in opposition along the major axis of each liquid crystal droplet.

23. A phoretic cell according to any of the preceding claims wherein the or each liquid crystal cell includes a dye.

24. A phoretic cell according to any of the preceding claims wherein the or each liquid crystal cell includes an oil soluble dye.

25. A phoretic cell according to claim 23 or 24 wherein the dye comprises at least one of a dichroic dye, an azo dye, an anthraquinone dye, a pharmaceutical dye, a cosmetic dye, a food dye, 1-hydroxy-4-[(4-methylphenyl)amino]-9,10-anthracenedione, 2-(2-quinolyl)-1,3-indandione, 1,4-bis[(4-methylphenyl)amino]-9,10-anthracenedione, 1-[[4-(phenylazo)phenyl]azo]-2 naphthalenol, solvent black 3, solvent black 5, solvent black 7, solvent black 12, solvent black 28, solvent blue 4, solvent blue 14, solvent blue 19, solvent blue 29, solvent blue 35, solvent blue 36, solvent blue 37, solvent blue 38, solvent blue 43, solvent blue 59, solvent blue 78, solvent blue 97, solvent blue 104, solvent brown 1, solvent brown 53, solvent green 1, solvent green 3, solvent green 4, solvent green 5, solvent green 7, solvent green 11, solvent green 28, solvent orange 1, solvent orange 2, solvent orange 7, solvent orange 15, solvent orange 20, solvent orange 23, solvent orange 60, solvent orange 63, solvent orange 105, solvent red 3, solvent red 19, solvent red 23, solvent red 24, solvent red 26, solvent red 27, solvent red 41, solvent red 43, solvent red 44, solvent red 45, solvent red 49, solvent red 72, solvent red 111, solvent red 135, solvent red 140, solvent red 179, solvent red 195, solvent red 207, solvent violet 8, solvent violet 13, solvent violet 37, solvent violet 59, solvent yellow 1, solvent yellow 2, solvent yellow 3, solvent yellow 7, solvent yellow 14, solvent yellow 33, solvent yellow 72, solvent yellow 93, solvent yellow 94, solvent yellow 98, solvent yellow 114, solvent yellow 141, solvent yellow 160, and solvent yellow 163.

26. A phoretic cell according to any of the preceding claims wherein the or each phoretic particle is adapted to reflect electromagnetic radiation incident thereon.

27. A phoretic cell according to claim 26 wherein the or each phoretic particle has a reflective coating comprising at least one of a metallic coating and a dielectric coating.

28. A phoretic cell according to any of claims 1-26 wherein the or each phoretic particle comprises a composite particle having a plurality of scattering particles adapted to scatter electromagnetic radiation incident thereon dispersed within a carrier.

29. A phoretic cell according to claim 28 wherein the carrier comprises a polymer.

30. A phoretic cell according to claim 29 wherein the carrier comprises polymethylmethacrylate (PMMA).

31. A phoretic cell according to any of claims 28 - 30 wherein the scattering particles comprise polymer spheres, each polymer sphere incorporating at least one of a gas cavity and crushed diamond.

32. A phoretic cell according to any of the preceding claims wherein the liquid crystal material is a Nematic liquid crystal material.

33. A phoretic cell according to any of the preceding claims wherein the applied field is at least one of an electric field and a magnetic field.

34. A phoretic cell substantially as herein before described with reference to figures 3 - 8 of the accompanying drawings.

35. A method for fabricating a phoretic cell as claimed in any of claims 6 - 18, or any of claims 23 - 33 when dependent on any of claims 6 - 18, having a plurality of phoretic particles suspended within a liquid crystal suspension medium, comprising the steps of

(i) preparing a first substrate having a first relief structure alignment layer adapted to interact with the liquid crystal suspension medium to provide a preferred alignment of the liquid crystal director within the phoretic cell,

(ii) forming a plurality of indentations within the relief structure alignment layer, each indentation having an internal surface extending from a relief structure surface of the relief structure alignment layer,

(iii) depositing the phoretic particles onto the first relief structure surface,

(iv) incorporating the liquid crystal suspension medium into the cell.

36. A method for fabricating a phoretic cell according to claim 35 comprising the steps of

(v) preparing a second substrate having a second relief structure alignment layer adapted to interact with the liquid crystal suspension medium to provide a preferred alignment of the liquid crystal director within the phoretic cell,

(vi) forming a plurality of indentations within the second relief structure alignment layer, each indentation having an internal surface extending from a relief structure surface of the second relief structure alignment layer,

(vii) arranging the second substrate remotely to the first substrate such that the relief structure alignment layer thereof interacts with the liquid crystal suspension medium to provide a preferred alignment of the liquid crystal director within the phoretic display.

37. A method according to claim 36 comprising the step of arranging each indentation in the relief structure surface of the first relief structure alignment layer substantially opposite a corresponding indentation in the relief structure surface of the second relief structure alignment layer, said indentations forming an opposing pair of indentations.

38. A method according to claim 37 comprising the step of arranging a phoretic particle within each opposing pair of indentations.

39. A method according to any of claims 35 - 38 wherein at least one of the first and second substrates comprises at least one of a polymer and a pre-polymer and the step of forming the plurality of indentations within the relief structure surface comprises an embossing process.

40. A method according to any of claims 35 - 38 wherein at least one of the first and second substrates comprises a photo-polymer and the step of forming the plurality of indentations within the relief structure surface comprises a photo-lithographic process.

41. A display having a first display surface for displaying an image, comprising a phoretic cell as claimed in any of claims 1 - 33,

wherein the phoretic cell is arranged within the display such that the or each first preferred position within the liquid crystal cell is located substantially at the first display surface,

the display being operable by the application of a field across the display.

42. A display according to claim 41 having a second display surface disposed remotely to the first display surface, comprising a phoretic cell as claimed in claim 2 or any of claims 3 - 33 when dependent on claim 2,

wherein the phoretic cell is arranged within the display such that the or each second preferred position within the liquid crystal cell is located substantially at the second display surface, and

the first and second preferred positions are such that the or each phoretic particle is visible at a display surface when located at one preferred position and is not visible at said display surface when located at the other preferred position.

43. A display according to claim 42 comprising a phoretic cell as claimed in claim 20 or any of claims 21 - 33 when dependent on claim 20, wherein the liquid crystal droplets are disposed within an encapsulant.

44. A display according to claim 43 wherein the encapsulant comprises at least one of a thermally curable polymer, a polymer curable by electromagnetic radiation and a silicone elastomer.

45. A display according to claim 43 or 44 wherein the encapsulant comprises Dow Corning® Sylgard® 182.

46. A display according to any of claims 43 - 45 comprising a phoretic cell as claimed in claim 22 or any of claims 23 - 33 when dependent on claim 22, wherein the liquid crystal droplets are arranged such that the major axis of the droplets is substantially orthogonal to a plane parallel with the first display surface.

47. A display according to any of claims 41 - 46 further comprising means for applying at least one of an electric field and a magnetic field across the display.

48. A display according to claim 47 wherein the means for applying the field comprises an electrode.

49. A display according to claim 48 when dependent on any of claims 42 - 47 comprising a plurality of electrodes arranged in rows adjacent the first display surface and in columns adjacent the second display surface, the intersection of each row and column electrode defining a pixel within the display, so as to enable matrix addressing of the pixels within the display.

50. A display according to claim 48 or 49 wherein the or each electrode comprises at least one of a metal, Indium Tin Oxide (ITO), and a conductive polymer.

51. A display substantially as herein before described with reference to figures 3-8 and 14 of the accompanying drawings.

52. A method of fabricating a display as claimed in any of claims 41 - 50 comprising the steps of

(i) dispersing a plurality of liquid crystal cells as described in claim 19 or any of claims 20 - 33 when dependent on claim 19, into a curable encapsulant,

(ii) aligning the liquid crystal cells into a preferred alignment,

(iii) curing the encapsulant to retain the liquid crystal cells therein.

53. A method of fabricating a display according to claim 52 further comprising the step of applying the dispersion of liquid crystal cells and curable encapsulant onto a substrate.

54. A method of fabricating a display according to claim 53 wherein the step of aligning the liquid crystal cells into a preferred alignment is performed after the encapsulant has been cured and comprises the step of expanding the cured encapsulant in a direction

substantially perpendicular to the substrate, thereby elongating the liquid crystal cells dispersed therein in a direction substantially perpendicular to the substrate.

55. A method of fabricating a display according to claim 54 wherein the step of expanding the cured encapsulant comprises introducing a material into the cured encapsulant so as to cause the cured encapsulant to swell.

56. A method of fabricating a display according to claim 53 comprising the intermediate steps of reversibly deforming the substrate in the plane of the substrate prior to curing the encapsulant and subsequently returning the substrate to its undeformed state after curing the encapsulant, so as to perform the step of aligning the liquid crystal cells, such that the cured encapsulant and the liquid crystal cells dispersed therein are compressed in a plane parallel with that of the substrate.

57. A method of fabricating a display according to claim 56 wherein the step of reversibly deforming the substrate comprises at least one of heating and stretching the substrate.